



Monenco

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REACTIVE ACID TAILINGS PROGRAM
PROGRAM DESIGN REPORT

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MICROMEDIA

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EXECUTIVE SUMMARY AND RECOMMENDATIONS

1. The recommended program of work for the Reactive Acid Tailings Program has been based on the recommendations of the "Sulphide Tailings Management Study", prepared by Monenco et al. (1984) and refined through a series of meetings with representatives from the mining industry, CANMET, provincial agencies, federal research groups, and the staff of other related programs such as the NUTS Program.

The principal components of the recommended program are shown in Table 2-1 (Page 2-4).

2. Proposals for jointly funded inputs to the Program were received from four mining companies: Cominco, Inco, Noranda and Falconbridge. These have been incorporated into the Program to the extent that matching CANMET funding is available.

The scope of the inputs to the Program can be greatly increased by taking advantage of several ongoing projects which do not require funding from the RATS Program. In this way, the total level of effort directed at the problem of acid-generating tailings can be increased to some \$888,500 in 1985, broken down as follows:

Industry Direct Expenditures	\$138,500
CANMET Direct Program Expenditures	\$146,000
Project Management Contract	\$ 50,000
Relevant Inputs Not Directly Funded	\$554,000
1985 Total Level of Effort	\$888,500

3. A relatively simple organization and system of program controls are recommended, based on a project manager reporting to a small Program Board, which would consist of senior CANMET and industry representatives. The project manager would be directly responsible to the Board for the coordination and management of all the Program components, but would draw on the advice and input of a relatively large Technical Advisory Panel on which a wide spectrum of industry, provincial, and federal

agencies, plus other knowledgeable individuals, would be represented. This arrangement is recommended to ensure strong, dynamic management of the Program, while taking into account the wide range of technical, scientific and regional considerations relevant to the Program (ref. Plate 3-1, page 3-2).

4. It must be emphasized that time is of the essence relative to the Federal Government (CANMET through Supply and Services Canada) contracting with the three companies providing core inputs in 1985 (i.e. Inco, Noranda and Falconbridge) so that advantage can be taken of the 1985 field season.

Appointment of the Program Manager, assignment of members to the Technical Advisory Panel, and awarding of a contract to undertake the conceptual design of the predictive techniques are also important tasks that must be undertaken with some urgency.

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PART ONE

INTRODUCTION

1.1 INTRODUCTION

The Reactive Acid Tailings Program was initiated by a request from the Metal Mining Industry to Canmet during the fall of 1983, with a view to addressing the widely-recognized problems associated with the abandonment or long-term management of acid-generating tailings. A definition of the issues and a recommended outline of the research required to address them were developed in a report entitled, "Sulphide Tailings Management Study", submitted to Canmet in July, 1984 (~~Monenco et al.~~ 1984). The concept of an industry/government cost-shared approach to undertaking the applied research outlined in the report was supported by Canmet, and, in March 1985, Monenco was retained to design a specific program of work. A copy of the executive summary of the Sulphide Tailings Management Report report is included as Appendix 1.

At the initial meetings held between representatives of the metal mining industry and Canmet, it was decided that the Program should emphasize the integration of a broad spectrum of practical tailings management investigations under field conditions. The objective would be to produce an inventory of practical techniques which ^{would} ~~will~~ enable the impact of acid-generating tailings to be sufficiently reduced so as to allow their ultimate abandonment without the need for ongoing treatment or maintenance.

The purpose of ^{that} ~~this~~ report ^{was} ~~is~~ to define the investigatory work required to meet the objectives of the Reactive Acid Tailings Program; to assess and integrate projects proposed by the mining industry for joint funding under the Program; to incorporate any other investigations or research work consistent with the Program objectives; and, to identify any gaps which should be filled by other means.

Initial inputs to the Program were obtained through a series of meetings arranged between representatives of mining companies having acid-generating tailings and officials of concerned provincial agencies in each of the provinces where there is a major acid tailings problem. Accordingly, such meetings were held in Victoria, Winnipeg, Toronto, Quebec City, and Fredericton. These meetings were very valuable, as they not only allowed industry representatives to outline the work which they felt necessary to address the long-term management of acid tailings but

also provided for a general exchange of information with provincial officials in the context of addressing regional objectives.

Summary notes of the provincial meetings are included in Appendix 2. The general enthusiasm, with which the introduction of the Reactive Acid Tailings Program was greeted, is indicative of the need for an integrated program to systematically find solutions to the problems of long-term tailings management.

PART TWO
PROGRAM DESIGN

2.1 OBJECTIVE

The objective of the Reactive Acid Tailings Program is ^{thus} to further develop techniques that will enable the base metal mining industry to ultimately abandon acid-generating tailings areas in a predictable, cost-effective and environmentally-acceptable manner.

Two main products of the Program are envisaged in meeting this objective. The first will be an inventory of tailings management techniques, covering as wide a range as possible of differing tailings characteristics, generic site conditions, regional considerations, etc. These will be presented as one or more state-of-the-art reports. The second product of the Program will be a series of predictive techniques which will enable the likely behaviour of acid-generating tailings to be determined at the mine-planning stage, given basic inputs on the chemical/mineral characteristics of the ore, local hydrologic/ hydrogeological parameters, site characteristics, and engineering data pertaining to the milling and tailings disposal systems.

Over the five-year timeframe of the Program, it is envisaged that a continuing cycle of data accumulation and review will lead to the development, refinement and testing of the predictive techniques. This sequence will also indicate in what manner the field studies should be adapted as the Program progresses. ~~This concept of continuing refinement, working from the primary inputs of predictive model design, field programs, and existing data, and leading to the final products of the Program, is shown diagrammatically in Plate 2-1.~~

~~As outlined in Part One,~~ the Program will be based on the integration of a wide range of practical tailings management investigations under field conditions, which will include research on both currently active and abandoned acid-generating tailings. This practical field program, which will be undertaken by mining companies contributing to the Program, will be supported by laboratory lysimeter work under controlled conditions and an ongoing review of both the literature and related work being conducted elsewhere.

~~Development of the Program components is based on the Sulphide Tailings Management Study (Monenco et al. 1984) and on the five industry/provincial meetings~~



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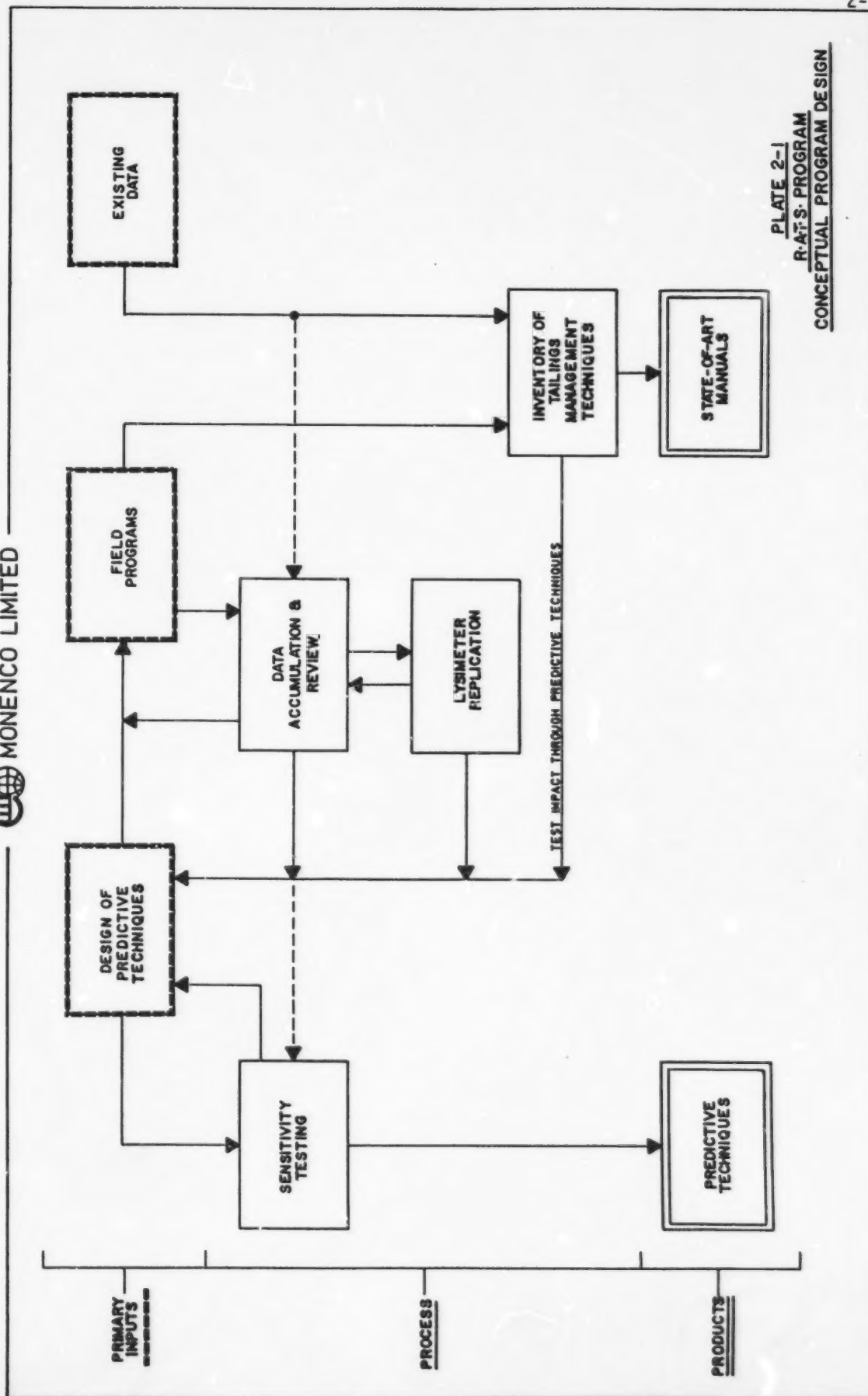


PLATE 2-1

R.A.T.S. PROGRAM

CONCEPTUAL PROGRAM DESIGN

~~described in Part One.~~ The scope of the Program is limited to acid-generating base metal sulphide tailings, and specifically excludes consideration of radionuclide effects or the oxidation of thio-salts, both of which are the subject of separate research programs. The Program is not intended to address the issues of acid-generating waste rock, although many of the findings of the Program may well be applicable to this problem, particularly from the standpoint of understanding the longterm oxidation of pyritic materials. The physical characteristics of waste rock storage piles are, of course, very different from those of tailings deposits. The Program will address the issues associated with both the design of new tailings disposal systems, as well as the management and reclamation of currently-active or abandoned deposits.

The following sections briefly review the four primary technical components of the program, as outlined in the Sulphide Tailings Management Study, namely:

- predictive techniques;
- tailings disposal systems;
- revegetation; and,
- effluent control.

These are shown in greater detail on Table 2-1. The fifth component, project management, is reviewed separately in Part Three of the report.

2.2 PRINCIPAL COMPONENTS

221 PREDICTIVE TECHNIQUES

Development of practical predictive techniques to enable the long-term behaviour of sulphide tailings to be evaluated under a wide range of disposal conditions is an extremely ambitious undertaking and might not be achieved within the timeframe of the Program. However, regardless of the direct success of such techniques, it is felt that inclusion of this objective in the Program is important because it will serve to focus the direction and analysis of the component studies. This will help provide a well-defined route to gaining an increased understanding



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TABLE 2-1
RATS PROGRAM COMPONENTS

REQUIRED INPUTS	ORGANIZATION'S PROPOSING INPUTS IN 1985	COMMENTS	REQUIRES EARLY ACTION
1. <u>PREDICTIVE TECHNIQUES</u> a) SURVEY & PROFILING OF ABANDONED DEPOSITS - PHYSICAL, CHEMICAL, GEOCHEMICAL - WATER BALANCE b) DESIGN OF PREDICTIVE MODEL (S) - DEFINITION OF APPROACH & KEY PARAMETERS - MODEL DEVELOPMENT & TESTING c) LABORATORY EVALUATION & LYSIMETER REPLICATION OF FIELD CONDITIONS d) FIELD EVALUATION & MODEL TESTING OF VARIOUS TREATMENTS: - VEGETATION - OTHER COVERS - FLOODING - BACTERIACIDES	INCO NORANDA MAJITOBA CAUMET (O+E.L.) INCO NORANDA TO BE CONTRACTED CAUMET (O) INCO NORANDA . COMINCO CAUMET FALCONBRIDGE CAUMET (O) FALCONBRIDGE NORANDA . CAUMET (E.L.) NORANDA	USED TO COORDINATE PARAMETERS & SAMPLING TECHNIQUES IMPORTANT EARLY INPUT. DEFINE TERMS OF REFERENCE FOR CONTACT. SPECIFIC STUDIES WILL BE REQUIRED AS PROGRAM PROGRESSES SEE 2a & 3 SEE 2d SEE 2e SEE 3d REQUIRES A GREATER VARIETY OF TAILINGS ALTERATIVE SYSTEMS TO BE ACTIVELY MONITORED THAN PRESENTLY PROPOSED. PROCESSING IS TENDING TOWARDS FINEER GRAIDS. (CONT...)	* * *
2. <u>TAILINGS DISPOSAL SYSTEMS</u> a) LONG TERM MONITORING OF EXISTING SYSTEMS - CHEMISTRY, BACTERIAL POPULATION, OXYGEN LEVELS, SEEPAGE, WATER CONTENT, PARTICULATE / PHYSICAL CHARACTERISTICS, COAGULOBIGATION, NATURAL AGING PROCESS. - LOW ACID UNVEGETATED - LOW ACID VEGETATED - HIGH ACID UNVEGETATED - HIGH ACID VEGETATED b) ALTERATIVE DISPOSAL SYSTEM DESIGNS & OPERATING METHODS - TENDS IN TAILINGS CHARACTERISTICS - PYRENOTITE / PYRITE SEGREGATION - REPROCESSING POTENTIAL			

TABLE 2-1 (CONT...)

3.	G) LONG TERM WATER BALANCE IN TAILINGS DEPOSITS H) NON-VEGETATIVE COVERS & SEALS CEMENTATION TECHNIQUES HARDPAN CHARACTERISTICS, BENEFITS, FORMATION E) UNDERWATER DISPOSAL - FLOODING F) DUST CONTROL G) LONG TERM DAM STABILITY H) COST IMPLICATIONS I) STATE-OF-THE-ART MANUAL (S) FOR R.A.T. SYSTEMS <u>REVEGETATION</u> A) CONSOLIDATION OF EXIST'G EXPERIENCE/KNOWLEDGE B) RESISTANT PLANT SPECIES C) SUCCESSION TECHNIQUES INCLUDING WETLANDS D) BACTERIACIDES TO HELP ESTABLISH GROWTH E) DEVELOPMENT & TESTING OF MAINTENANCE-FREE VEGETATION F) IMPACT OF VEGETATION ON TAILINGS OXIDATION G) STATE-OF-THE-ART REVEGETATION MANUAL	NOBANDA, INCO, CANMET (E.L.) FALCONBRIDGE CANMET (O) MANITOBA BRUNSVICK MINING INCO, FALCONBRIDGE INCO, FALCONBRIDGE FALCONBRIDGE INCO, NOBANDA, COMINCO FALCONBRIDGE INCO, NOBANDA, CANMET (O&E)	NUTS PROGRAM TO LET STUDY ON SEALS IN 1988. CANMET UNDERTAKING LYSIMETER STUDY IN OTTAWA. NO PROPOSAL RECEIVED BUT INTEREST IN EVALUATING DUST CONTROL EXPRESSED BY BMS NUTS PROGRAM TO LET STUDY IN 1988 WILL PROBABLY REQUIRE SPECIFIC CONTRACT.	*
4.	<u>EFFLUENT CONTROL</u> A) LOW MAINTENANCE REMOTE SEEPAGE TREATMENT SYSTEMS. B) PASSIVE POLISHING TECHNIQUES	INCO, FALCONBRIDGE CONTRACT RECOMMENDED	REF: SEE REPORT SECTION 3-3 IMPORTANT TO HAVE SYSTEMS IN PLACE PRIOR TO AUTHORIZING WORK. (CONT...)	*
5.	<u>PROJECT MANAGEMENT</u> A) Ongoing INTEGRATED DATA ASSESSMENT			

TABLE 2-1 (CONT...)

	b) QUARTERLY PROGRAM EVALUATION & TUNING c) DEFINITION & INTEGRATION OF PROGRAM ADDITIONS d) MANAGEMENT REVIEW MEETINGS e) INFORMATION DISSEMINATION f) COST & SCHEDULE CONTROL-REPORTING.		REF: FIG. 3-2 NOTE: CANMET (O) : OTTAWA CANMET (E-L) : ELLIOT LAKE	
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of the many factors influencing acid formation and of the inter-relationships between these factors.

The development of a single predictive model, should this in fact be practical, will probably result from the integration of a number of techniques, probably involving the modelling of the water balance on the one hand and chemical/physical transformation of the tailings on the other.

The definition of the concept for developing predictive techniques and of the key parameters required for their successful application is therefore seen as an important input during the early phases of the Program so as to provide focus to the site-specific work undertaken at the various tailings sites under investigation. Similarly, sensitivity testing and refinement of the inputs to the predictive techniques will provide very specific direction to the Program as it progresses.

Laboratory evaluation of conditions found in the field will almost certainly be required and the design of specific lysimeter studies to replicate the linkages between controlling reactions over time will be important to understanding the aging process of acid-generating tailings.

An ultimate objective of the predictive techniques will be to evaluate the relative effectiveness of different tailings management methods such as vegetation, other types of cover, flooding, bacteriacides, etc. It will therefore be important to collect sufficient data on the influence of these treatments on acid generation to enable their effects to be integrated into the predictive models and tested.

222 TAILINGS DISPOSAL SYSTEMS

As indicated in Table 2-1, there are a wide range of issues relating to tailings disposal systems which require investigation under practical operating conditions. The approach proposed to obtaining the required level of knowledge of these alternatives as a function of the RATS Program is to:

- (a) evaluate and monitor examples of various disposal methods and control systems as they exist in Canada; and,
- (b) obtain operating data and characteristics of similar systems existing elsewhere, including U.S., Europe, USSR, etc.

Long-term monitoring of acid-generating tailings systems is included under this category of tasks, as well as under (1a), in order to emphasize the importance of understanding as wide a range of existing systems as possible. Monitoring under this category will provide input to several of the following specific topics, including: tailings water balance (2c); the impact of various tailings system configurations on the long-term behaviour of the tailings (2b); hardpan formation and its effects (2d); and the relative merits of underwater tailings disposal (2e). This last item is felt to be of particular interest due to the low rate of oxidation and relative impact of acid-generating tailings disposal underwater as compared to land-based systems. Although underwater disposal is not an available alternative for many mining operations, it will be important to achieve a better understanding of its effectiveness and long-term implications, particularly as it has, until recently, been discouraged from the regulatory standpoint.

A number of the topics identified under "Tailings Disposal Systems" in Table 2-1 are being addressed in the National Uranium Tailings (NUTS) program and should be applicable to the RATS program. The NUTS program, for example, is developing an atmospheric model including dust uptake and dispersion, it has considered the use of bacteriacides, and is planning to fund studies to investigate non-vegetative seals and long-term dam stability. It is apparent that a close working relationship between the RATS and NUTS programs will be of considerable mutual benefit.

The final product of the various tasks identified under "Tailings Disposal Systems" will be one or more state-of-the-art manuals defining long-term tailings management techniques such as non-vegetative covers, underwater disposal, preferred tailings system designs and operating methods, etc.

223 REVEGETATION

The establishment of a self-sustaining biomass as a cover to acid-generating tailings is widely recognized as a desirable approach to the long-term management of many deposits. However, the specific benefits and effects of revegetation need to be better understood and, in particular, continuing research is required relative to the amendment of tailings as a growth medium, species selection, long-term self-perpetuation, as well as the effects of different vegetative covers on the long-term oxidation of the underlying tailings.

Items 3(b) and (c) in Table 2-1 recognize the importance of building an organic surface layer through a succession of plant forms utilizing species that have a natural ability to survive under the conditions prevailing at a given site.

224 EFFLUENT CONTROL

It is important that the Program recognize that the complete elimination of acid, metal-bearing, seepage from sulphide tailings disposal areas is virtually impossible. Thus, in cases where the quantity and/or quality of such "final effluents" exceed the assimilative capacity of the receiving systems, some form of long-term treatment or control will be required. The objective of this component of the Program is therefore to investigate low maintenance remote seepage treatment systems and passive polishing techniques, which could become an integral part of a long-term management system for a specific tailings deposit.

2.3 PROPOSED PROGRAM INPUTS

Proposed inputs to the RATS Program, as of May 30th, 1985, are summarized in Table 2-2. The inputs which these projects will provide relative to the required Program components (Table 2-1) are indicated and referenced back to Table 2-1.

A brief description of each proposed program is included in the following sections.



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TABLE 2-2
PROPOSED PROGRAM INPUTS AS OF 85-05-30

ORGANIZATION	PROGRAM CATEGORY & DESCRIPTION (REF. TABLE 2-1)	TOTAL COST (MILLIONS) CAPITAL & INDUSTRY					COMMENTS	
		1985	1986	1987	1988	1989 TOTAL		
INCO LIMITED (LEVACK TAILINGS)	1a PROFILE EXISTING DEPOSITS	245K	155K	195K	99K	-	615 K	PROGRAM BUDGET MODIFIED - SEE SECTION 2.4
	1b LYCHETER REPLICATION/CALIBRATION							
	1c VEGETATIVE COVER IMPACT							
	2a MONITORING OF EXISTING SYSTEMS							
NORANDA INC. (VAUTE-AVILLET TAILINGS)	3a RESISTANT PLANT SPECIES							
	3b SUCCESSION TECHNIQUES							
	3c MAINTENANCE-FREE VEGETATION							
	3f IMPACT OF REVEGETATION ON OXIDATION							
COMINCO (GULLNAN CONCENTRATOR)	3c MAINTENANCE-FREE VEGETATION	165K	150K	75K	75K	-	450K	PROGRAM BUDGET MODIFIED - SEE SECTION 2.4
FALCONBRIDGE	1a FIELD EVALUATION - BACTERIACIDES	285K	163K	25K	18K	122K	152K	COST DISTRIBUTION NOT SPECIFIED REF. SEC. 242.4
	3b RESISTANT PLANT SPECIES	47K	26K	28K	25K	31K	155K	
	3c SUCCESSION TECHNIQUES - VETLANDS	31K	20K	15K	12K	12.5K	88.5K	POSTPONED - SEE SECTION 2.4
	4b PASSIVE POLISHING TECHNIQUES	-	-	50K	33K	33K	99K	
MANITOBA MINES & ENERGY	1a SURVEY OF ABANDONED TAILINGS	78K						NO COST TO E.A.T.S. PROGRAM
HEATH STEELE MINES	2g ALT. COVERS & SEALS (TREATMENT SLUDGES)							NO HIGH FUNDS AVAILABLE BUT MAY BE VIABLE UNDER U.S. MIN. DEV. AGREEMENT
BRUNSVICK MINES	2h DUST CONTROL							NO FUNDING PROVIDED FOR 1985

TABLE 2-2 (con'd)

ORGANIZATION	PROGRAM CATEGORY & DESCRIPTION (REF. TABLE 2-1)	TOTAL COST (1985 DOLLARS) CANMET & INDUSTRY					COMMENTS
		1985	1986	1987	1988	TOTAL	
CANMET-OTTAWA	1a PROFILE EXISTING DEPOSITS	40K	40K	40K	40K	200K	NO COST TO R.A.T.G. PROGRAM
	1c LYSIMETER REPLICATION	16K	16K	16K	16K	80K	
	2d NON-VEGETATIVE COVERS - WOOD DEBRIS						
CANMET-ELLIOT LAKE	1a PROFILE EXISTING DEPOSITS	240K	240K	240K	240K	1200K	NO COST TO R.A.T.G. PROGRAM
	1c LONG TERM MONITORING OF EXIST. SYSTEM	100K	100K	100K	100K	500K	
	1d UNDERWATER DISPOSAL						
	2d NON-VEGETATIVE COVERS						
	3f EFFECT OF VEGETATION ON TAILINGS OXIDATION						
PROJECT MANAGEMENT	5	50K					1985 CONTRACT FOR PROJECT MANAGER
							NOTE: a) - CANMET INTERNAL BUDGET b) - CANMET CONTRACT BUDGET

231 INCO LIMITED - LEVACK TAILINGS

Inco Limited is proposing a series of research projects on its Levack tailings area in Sudbury, Ontario. These projects will utilize an approach generally referred to as "ecological engineering" to address the following topics:

- converting wet tailings areas into wetlands which will provide an oxygen barrier between the acid-generating tailings and the environment;
- developing a moss root layer on dry areas which will reduce penetration of precipitation to the tailings and provide an oxygen-consuming organic layer;
- providing a self-maintaining algal population in seepage areas to polish the seepage; and,
- developing bogs in water bodies on the tailings surface to increase primary production with a reduced rate of decay.

The pilot program will be designed to establish a methodology to initiate and sustain these ecosystems and evaluate their effect on the groundwater and surface water runoff quality.

The following questions will be evaluated in this study:

- Can the ecosystems be initiated?
- Is oxygen penetration prevented by the ecosystems?
- Is there significant improvement on the seepage and runoff water quality?

The Levack tailings area is felt to be an ideal test site for this research, as it has the following characteristics:

- the site includes a "difficult" surface cover of pyrrhotite;
- the site has an acidic surface and an acidic small creek flowing on the tailings surface;
- the site has typical low pH seepage areas;

- the site has a typical acidic pond from groundwater discharge (gravel pit);
- historic records of the groundwater characteristics are available and the groundwater appears to have been affected by the tailings;
- the site has an alkaline water source (mine water discharge) which may be used to represent a treatment system;
- the site is easily accessible; and,
- the tailings surface has dry areas which will remain dry.

232 NORANDA INC. - WAITE AMULET TAILINGS

Noranda Inc. are proposing a series of projects on the Waite Amulet tailings area in Noranda-Rouyn, Quebec. This tailings area consists of approximately 160 acres of high acid-generating sulphidic tailings (30% sulphur). Sixty percent of the area is revegetated, the rest not. The following investigations are proposed over a five-year timeframe:

- measure hydrogeology of the tailings area and establish local geology, surface hydrology and groundwater flow regimes;
- measure geochemistry of the tailings area groundwater by installing piezometer nests along the major groundwater flow paths within the tailings and surrounding aquifer and establish contaminant plumes (if any);
- measure quantity and quality of the surface water entering and leaving the tailings area;
- obtain solid core samples from the tailings area and analyze for physical and chemical properties (moisture content, grain size, mineralogy, etc.) at different depths;
- collect meteorological data and develop an area water balance; and,
- assess the effect of vegetation on water quality and quantity and evaluate long-term revegetation viability.

233 COMINCO-SULLIVAN CONCENTRATOR

Cominco's Sullivan Concentrator in Kimberley, British Columbia, has more than 900 acres covered with acid-generating tailings. Cominco proposes to construct an experimental site of approximately 2.5 acres on the iron tailing pond, using float rock and gypsum. This will enable studies to be implemented which will:

- assess effect of gypsum depth on vegetation establishment, growth and quality under the semi-arid climate at Kimberley;
- monitor uptake and accumulation of fluorine by vegetation growing on gypsum; and,
- develop revegetation techniques which sustain vegetation containing acceptable concentrations of fluorine.

234 FALCONBRIDGE

Falconbridge Limited are proposing four investigations on acid-generating tailings at their Sudbury, Ontario, operations:

1. Developing a technique for reclamation of high iron and sulphur tailings by establishing marshland.

This work is proposed at the Fault Lake tailings area, which consists of approximately 70 acres of pyrrhotite/tailings mix and would involve flooding cells of the tailings area and transplanting aquatic plants from neighbouring areas.

2. Developing a long-term treatment strategy upon abandonment of a high-sulphur tailings area.

This investigation would be centred on the "Falconbridge Conservation Area", which is a natural black spruce bog several hundred acres in size which was totally destroyed by fire and the impact of the neighbouring smelting process. Recent detoxification of the area by directing treated wastewater through the area has resulted in natural re-establishment of a relatively productive marshland.

The objective of the investigation will be to characterize the rehabilitation process, taking into account biological, bacteriological, physical and chemical parameters.

3. A comparative study of 3 methods of reducing acid generation and metals released from waste rock and tailings.

This research proposal will focus on the use of anti-bacterial agents such as sodium lauryl sulphate, and phosphates plus the use of municipal garbage to reduce pyrite oxidation. A comparison of the impacts of these methods on waste rock and tailings will be made.

4. Investigation of the natural removal of nickel from solution by lake ecosystems.

This project is similar in principle to that described in Section 231, and will investigate the removal of nickel by bacterial or algal species in Lower Moose Lake. Sediment studies will be performed to help determine which species are removing nickel, and the fate of this nickel. Attempts will be made to determine if this metal is in a stable form or if it will redissolve and flush during high flows. The impacts of lake turnover will be evaluated, both from the standpoint of nutrient recycling and metal release from the sediments.

235 MANITOBA MINES ENERGY

The Manitoba Department of Mines and Energy has, as a function of its Mineral Development Agreement, retained Acres International to investigate the effect of natural stabilization processes on several long-abandoned tailings deposits in Manitoba. The deposits to be investigated include:

Tailings	Years of Operation	Disposal Method	Time Abandoned
Mandy	1943-44	Underwater NW Arm Schist Lake	41 years
Sherridon	1931-32 1937-51	Tailings Pond	34 years
Lynn Lake	1953-76	Tailings Pond	9 years

The project will investigate the physical, chemical and bacterial characteristics of the tailings column, check the groundwater characteristics in the tailings, as well as evaluate the environmental effects of the tailings. The field work will be undertaken during the 1985 season and the final report is scheduled for February 1986.

At the meeting with officials of the Manitoba Department of Mines & Energy, held on April 4, 1985 (see Appendix 2) it was agreed that the data from this project would be available to the RATS program and that a comparative exchange of other information with a view to avoiding duplication would be maintained between the Province and RATS Program Management.

236 HEATH STEELE MINES

As indicated in the New Brunswick Program meeting held on April 16, 1985 (see Appendix 2), Heath Steel Mines is currently in the situation of maintaining its extensive contaminated surface and minewater treatment systems while having its mining and milling operations suspended. Thus no tailings are being produced but significant volumes of acid treatment sludge are being pumped to the tailings disposal area.

Heath Steele tailings are extremely high in pyrite (approximately 70%) and have been the subject of prior physical/chemical/bacterial investigation (Boorman et al. 1974).

Due to their negative cash flow Heath Steele Mines Limited cannot directly fund an input to the RATS program but would be pleased to cooperate with any research efforts that might be independently funded. Discussions are currently in hand with of the New Brunswick Department of Natural Resources to determine if the unique situation afforded by the Heath Steele situation can be investigated to benefit of the RATS Program under the auspices of the New Brunswick Mineral Development Agreement.

237 BRUNSWICK MINING AND SMELTING

Brunswick Mines has indicated its interest in submitting a proposal for joint funding under the RATS program to evaluate the long-term control of dusting from tailings areas as a function of the reclamation process. At the time of writing, no formal submission had been received.

238 CANMET - OTTAWA MINERAL SCIENCES LABORATORY

The Mineral Sciences Laboratory (MSL) Directorate of Canmet has, for several years, been operating a number of lysimeter experiments with a view to "providing information on the generation and migration of acid, anions and cations and on the effects of vegetation, bacteria, water flow, oxygen levels and silts on tailings chemistry under controlled conditions" (Campbell 1985).

MSL is proposing to conduct or maintain the following lysimeters based experiments, the results of which will be of benefit to the RATS Program:

- Maintain and monitor two Elliot Lake uranium tailings (low sulphide) (1 ton);
- Set up, maintain and monitor a high pyrite (Noranda) tailings (1 ton);
- Maintain and monitor a number of small lysimeters of varying sulphide content;
- Test about 4 different Elliot Lake bog materials for possible application as an oxygen barrier to sulphide oxidation in tailings; and,
- Set up, maintain and monitor 2-simulated deep lake tailings lysimeters (Elliot Lake and Noranda Horne), also containing fish.

In addition, MSL propose a series of tests to determine the effectiveness of wood waste to produce sulphate reducing bacteria and thus provide treatment of acid mine water when applied to a centrifugal disc machine using wood waste as a contact media. The following work plan is proposed:

1. Determination of the effect of different variables of the machine on the water-flow through the wood waste.
2. Determination of water purification and possible metal separation in Elliot Lake tailings effluent and an artificial salt solution.
3. If results are successful, determination of capacity and concentration simulating the use of a battery of discs.
4. Survey market, select or design and develop, monitor control equipment for experiments on the use of woodwaste for acid mine water pollution abatement - 1985.
5. Contract out the construction of the arrangement to be used in the extended experiments - 1986.

A third set of experiments are proposed to determine the bacterial population and oxygen barrier mechanisms when tailings are covered with bog:

1. Assessment of types and population of bacteria in all lysimeters employing bog cover and compared with those without the cover.
2. Assess bacteria type and population in the as-received bog prior to use.
3. Determine the oxygen-barrier mechanisms that provide for acidity control.
4. Identify and determine why the particular bacteria are prevalent in the bog prior to placing on tailings.
5. Determine the humate content in bog (before and after placement on tailings) and whether there is a relationship between humates and bog bacteria.

239 CANMET - ELLIOT LAKE

Four projects are being undertaken by Canmet at their Elliot Lake research facilities which will provide relevant inputs to the RATS program. These are described as follows:

1. Physical and Chemical Characterization of Tailings

Existing abandoned tailings are being studied to characterize physical and chemical properties. These include particle size, porosity, moisture content, hydraulic conductivity, pore gas concentrations, chemical concentrations of both solid and liquid phases.

2. Contaminant Migration From Tailings

Migration of contaminants from tailings to the surrounding aquifers. These include hydrogeochemical investigation of tailings, pore water migration, contaminants plume, reaction with buffering and neutralizing material, contaminants dispersion and diffusion rates and retardation of various species.

3. Underwater Storage of Tailings

Long-term acid production potential and diffusion of contaminants from underwater buried tailings is being studied in a laboratory-based lysimeter scale investigation. The role played by various reducing bacteria is also being investigated in order to control acidity in the effluent.

4. Tailings Stabilization and Cover Technology

Various vegetative and non-vegetation tailings covers are being evaluated for long-term physical and chemical stability of tailings. The project also involves use of tailings as backfill.

2310 NATIONAL URANIUM TAILINGS PROGRAM (NUTP)

The NUTS Program was established in 1982 with an approved working budget of \$9 million over a period of 5 years. The Program is placing a heavy emphasis on the development, testing and application of modelling techniques as the means to understand and predict the long-term behavior of uranium tailings. There is naturally a heavy emphasis on radionuclide dispersion and pathways but the Program addresses a number of issues related to sulphide tailings which are of direct benefit to the RATS Program. As an example, the system model currently being developed will address the issue of sulphide oxidation in tailings deposits and should, therefore, provide an excellent starting point for the initial design of the predictive model proposed for the RATS Program. An initial draft of the NUTS model should be available in June, 1985 and is therefore very timely, relative to the initiation of the RATS Program. Also, as mentioned in Section 222, the NUTS

Program will address a number of general topics related to tailings disposal systems, including:

- dust uptake and dispersion
- use of bacteriacides
- non-vegetative seals
- long-term dam stability
- distribution of catastrophic effects, including flooding, earthquake, major forest fires, etc., which might influence the long-term management of tailings deposits.

It is obviously important that close liaison be maintained between the two programs to avoid duplication and to benefit wherever possible from work already undertaken or in progress as part of the NUTS Program.

2.4 RECOMMENDED 1985 PROGRAM & BUDGET

241 BUDGET ALLOCATION

The foregoing section outlines the proposed inputs to the RATS Program at the time of writing. The limit of CANMET direct financial input for jointly funded projects for the 1985-86 calendar year is \$150,000.00. Thus, there is a need for some allocation between the various programs proposed, at least for the current year. Discussions with officials of CANMET and industry representatives during the course of the project design, lead to the decision that the following allocation of the 1985-86 CANMET funding would be most appropriate:

	<u>Industry Input</u>	<u>CANMET Input</u>
Inco Levack Tailings	\$50,000	\$50,000
Noranda Waite Amulet	50,000	50,000
Falconbridge	38,500	21,000
Conceptual Design of Predictive Techniques	0	25,000
	\$138,500	\$146,000

Thus, the total level of effort on the core projects in 1985 would be \$284,500.

In addition to those projects specifically funded under the RATS Program, the level of effort directed toward the problem of acid-generating tailings and coordinated into the Program would be increased by the following inputs:

-	Manitoba Mines & Energy Abandoned Tailings Investigation	\$ 78,000
-	CANMET - Ottawa Lysimeter Work	56,000 ^a
-	CANMET - Elliot Lake Field Studies	340,000 ^b
-	Heath Steele Mines - N.B. Mineral Development Agreement	(est.) 80,000
-	NUTS Program Inputs	no value allocated ^c
	Total Inputs Not Directly Funded	\$554,000

a, b These projects, while relevant to RATS, are not designed to meet specific objectives of the Program. Allocation of total funding as representing the level of effort directed toward RATS may therefore be exaggerated. On the other hand, item (c) will provide considerable benefits for which no allocation is included.

If the project organization recommended in Section 3.1 is adopted, there is considerable benefit in contracting out the project manager role and an allowance of \$50,000 (40K cost-of-time + 10K expenses) payable by CANMET should be included

in the overall budget. The distribution of funding representing the total level of effort directed towards RATS in 1985 would therefore be as follows:

Industry Direct Expenditures	\$ 138,500
CANMET Direct Program Expenditures	146,000
Project Management Contract	50,000
Relevant Inputs Not Directly Funded	554,000
1985 Total Level of Effort	\$ 888,500

242 1985 JOINTLY FUNDED PROJECTS

The proposals for jointly funded projects, as initially submitted, are described in Section 2.3. The majority of these have had to be modified somewhat to meet the constraints of the available Program budget. The specific work recommended for 1985 is therefore as follows.

.1 Inco Limited

The budget for this project will be limited to \$100,000 in 1985, evenly split between Inco and CANMET. While the overall objectives and scope of the project remain as described in Section 231, the emphasis in 1985 will be placed on the following:

- testing different introduction and expansion methods for establishing indigenous biota in the proposed experimental areas; and,
- demonstrating the cleansing effect of filamentous green algae on seepage water.

The work proposed for 1985 is, therefore, considered a summer season of test work to determine the feasibility of proceeding with the implementation of the proposed program. A first assessment of the biological work would be made by the end of the field season in October.

Funding requirements for subsequent years will depend on the findings of the 1985 Program.

.2 Noranda Inc.

As for the Inco project, this input will be limited to a total budget of \$100,000 in 1985, evenly split between Noranda and CANMET. The objectives of the project, as described in Section 232, will be maintained. Activities during 1985 will include:

- Preliminary evaluation of surface water levels and collection of near surface water and soil samples to provide a hydrogeologic setting and extent of tailings deposition. Location of surface runoff monitors and preliminary boreholes will be established during 1985.
- A preliminary drilling program will be started with on-tailings and off-tailings boreholes for core sampling and piezometer installations. Analysis of core samples will provide hydraulic conductivity, porosity grain size, oxidized-unoxidized zones and bacterial counts.

Suggested funding for the balance of the program is as follows:

	<u>1985</u>	<u>1986</u>	<u>1987</u>	<u>1988</u>	<u>1989</u>	<u>Total</u>
CANMET	\$ 50,000	\$125,000	\$ 45,000	\$ 25,000	\$ 30,000	\$275,000
Noranda	50,000	100,000	30,000	50,000	45,000	275,000
	<u>\$100,000</u>	<u>\$225,000</u>	<u>\$ 75,000</u>	<u>\$ 75,000</u>	<u>\$ 75,000</u>	<u>\$550,000</u>

.3 Cominco Limited

The test plot described in Section 233 was established in terms of the basic placement of materials in 1984 with the assistance of funding from CANMET. The primary activity in 1985 therefore will centre on seeding and allowing the vegetation to become established. Monitoring of the yield and analysis of vegetation for mineral uptake will be undertaken, but no further funding of the project

will be required from CANMET in 1985. The scope of the work and therefore funding required in 1986 and subsequent years will depend on the findings of the 1985 investigations.

.4 Falconbridge Limited

In order to observe budget constraints, the second project proposed by Falconbridge Limited (see Section 234) will not be started in 1985. Projects 1 and 3 however will be undertaken as described. Project 4 is not scheduled to start until 1987.

Work proposed in 1985 for the two projects is as follows:

Project 1 - Reclamation by Establishing Marshlands:

- establish 3 test cells of 1 acre each on Fault Lake tailings area
- flood to maintain 1' - 3' cover at all times
- line cell 1 with 1" - 2" sewage sludge; add lime and fertilizer to cell 2; leave cell 3 untreated
- plant each area with locally available marshland plants, including cattails, clara, potamogeton, ulothix, spirogyra, etc.
- monitor surface and seepage quality (SO_4 , Ni, Fe, Cu, NO_3 , Kjeldahl N, P, pH); plants for metal uptake, condition, rate of coverage, growth rate, etc.

Project 3 - Reduction of Acid Production by Antibacterial Agents and Garbage

Laboratory

- establish 5' x 6" leach columns of 3/4" ore, inoculate with Thiobacillus ferrooxidans
- test leach columns with the following to determine best chemical for 1986 field trials: sodium lauryl sulphate, calcium, phosphate, hydrated lime

Project 3 - Reduction of Acid Production by Antibacterial Agents and Garbage (cont'd)

Field

- establish 3 one-acre plots on abandoned Feccunis tailings, including berms and sand points for collection of surface and groundwater
- place 3'-4' waste rock and sewage in plot 1, 3'-4' of municipal garbage of plot 2, and leave plot 3 as control
- monitor surface and groundwater over period of five years

The distribution of funding for these two projects over the five-year period proposed is as follows and results in a heavier initial distribution of costs towards the mining company, although the 50:50 balance of funding is achieved for each project over its lifespan:

	<u>1985</u>		<u>1986</u>		<u>1987</u>		<u>1988</u>		<u>1989</u>		<u>Total</u>	
	Co.	CMet	Co.	CMet	Co.	CMet	Co.	CMet	Co.	CMet	Co.	CMet
Proj. 1	16.0	16.0	9.5	11.5	7.5	6.5	6.5	6.0	6.5	6.0	46.0	46.0
Proj. 2	23.5	5.0	20.3	48.0	15.0	10.0	10.0	8.0	7.2	5.0	76.0	76.0
	—	—	—	—	—	—	—	—	—	—	—	—
	38.5	21.0	28.8	59.5	21.5	16.5	16.0	14.0	13.7	11.0		

243 OVERVIEW

.1 1985 Program

The above jointly funded projects provide an excellent start to the RATS Program for 1985, particularly when complemented with the other not-directly-funded inputs outlined in Section 241. Referring to Table 2-1, the jointly funded projects will provide a start on at least the following program components:

	<u>Item</u>
- predictive techniques	1b ^a , 1d
- long-term monitoring of existing tailings systems	2a
- water balance in tailings systems	2c
- non-vegetative covers	2d
- resistant plant species	3b
- succession techniques including wetlands	3c
- bacteriacides	3d
- development and testing of maintenance-free vegetation	3e
- impact of vegetation on tailings oxidation	3f
- passive polishing techniques	4b
- project management	5a

a Assumed to be directly funded by CANMET as part of core RATS Program.

The not-directly-funded inputs to the Program will supplement many of the above topics and add the following to the list of Program components being addressed during 1985:

- lysimeter replication of field conditions	1c
- underwater disposal	2e
- remote seepage treatment systems	4a

It must be emphasized that the work program recommended for 1985 will, in many cases, provide only an introduction to the Program components listed above. Efforts on these items will have to be extended in both scope and depth to meet the long-term objectives of the Program. Nevertheless, this process of refinement can be achieved through the Program review recommended for the fall of 1985 (see Section 3.5). The important thing, at this time, is to mobilize the 1985 program

by contracting the companies to be involved as expediently as possible so as to take advantage of the 1985 field season.

Appointment of the Program Manager, assigning representatives to the Technical Review Panel, and awarding a contract to undertake the conceptual design of the predictive techniques are also important items to be undertaken on an immediate basis.

.2 Post-1985 Program

As mentioned in the foregoing section, many of the Program components being addressed in the 1985 program of work will require broadening in scope and/or depth as the Program progresses. This is seen as a normal evolutionary function to be directed by the Project Manager with assistance from the Technical Review Panel. In addition, the means must be found in future Program years to address the following components, as outlined in Table 2-1:

-	Alternate Disposal System Designs & Operating Methods, including	2b
	- trends in tailings characteristics	
	- pyrrhotite/pyrite segregation	
	- reprocessing potential	
-	Cementation Techniques	2d
	Hardpan Characteristics, Benefits, Formation	2d
-	Dust Control	2f
-	Long-term Dam Stability	2g
-	Cost Implications	2h
-	Low Maintenance Remote Treatment Systems	4a
-	Review of methods, systems and data in U.S. Europe, Asia and elsewhere	ref. see 222

PART THREE

PROGRAM ORGANIZATION

3.1 INTRODUCTION

The challenge of the Reactive Acid Tailings Program is to direct the efforts of a wide range of Program components, many of which are specific to the individual needs of mining operations in widely differing conditions across the country, into a cohesive integrated program which will have tangible benefits to the industry as a whole by providing the means for long-term management of acid-generating tailings.

To achieve the necessary level of synergism between the component programs, it is essential that the program be managed in a dynamic manner, yet it is also important that the many participants and interested parties be actively involved in a participatory manner. To meet these objectives, the organizational structure shown in Plate 3-1 is proposed. Each element of this organization is discussed in the following sections.

3.2 PROGRAM BOARD

It is assumed that overall responsibility for the Program will rest with a Program Board. It is suggested that this Board should include the Director of the Mineral Science Laboratory (CANMET), the Director of the Mining Research Laboratory (CANMET), the Senior Canmet Project Officer and a senior representative of the mining industry. This group would be chaired by the Director of the Mineral Sciences Laboratory (W.A. Gow).

3.3 PROJECT MANAGER

The focal point of the Program and its ongoing management is the Program Manager. He should be an individual knowledgeable in the broad range of issues associated with acid-generating tailings, acceptable to the Program participants, and possessing the necessary interpersonal and management skills.

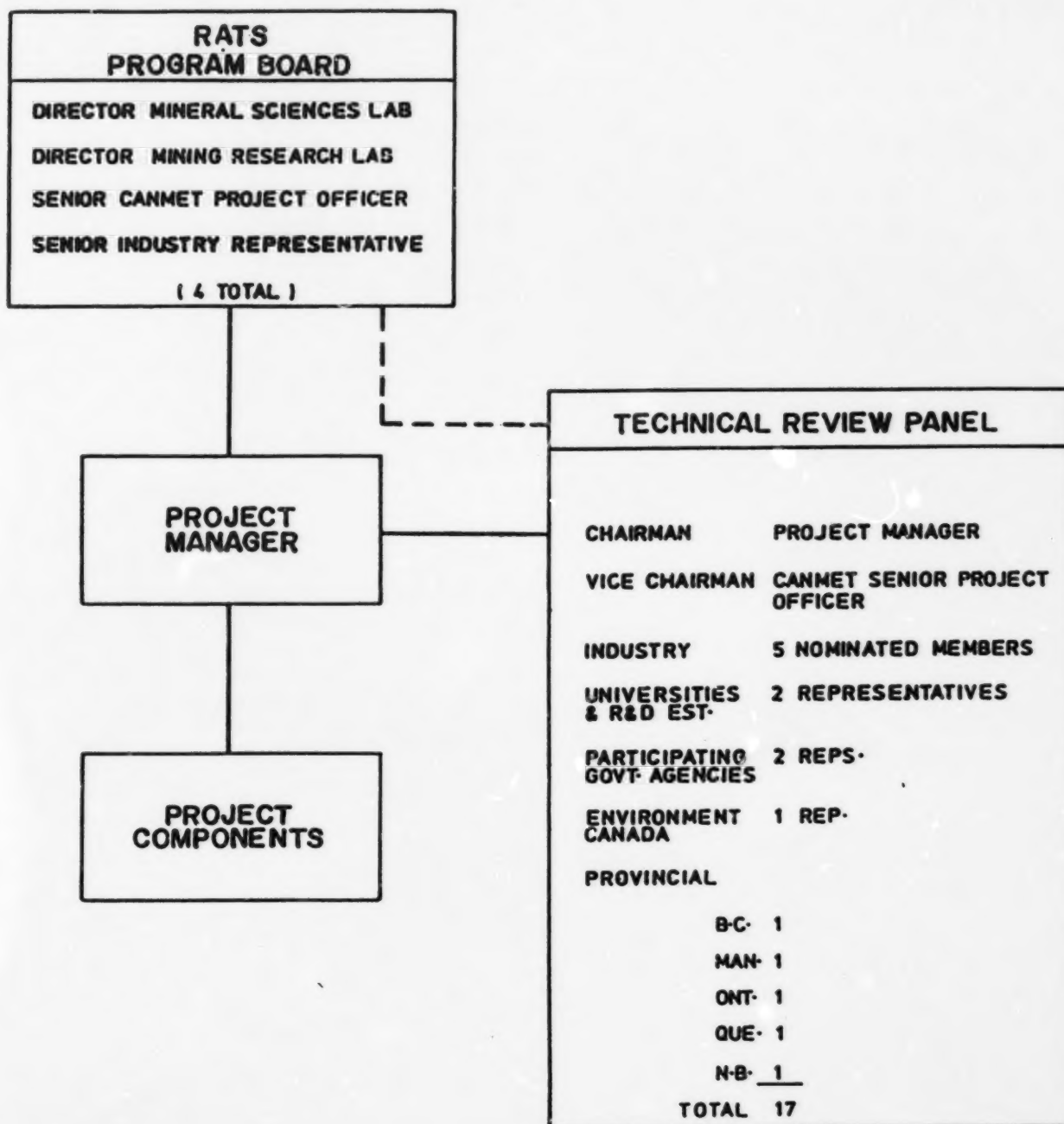


PLATE 3-1
REACTIVE ACID TAILINGS PROGRAM
PROPOSED ORGANIZATION

This would not need to be a full-time role, but would obviously involve intermittent periods of full-time activity associated with review meetings, report preparation, site visits, etc.

Key responsibilities of the Project Manager would be as follows:

- to ensure, on behalf of the Program Board that the objectives of the Program are achieved in a cost-effective and acceptable manner;
- to provide ongoing management to the Program on behalf of the Program Board;
- to maintain technical liaison, scheduling and cost control between the various Program components;
- to organize and chair regular Technical Review Panel meetings and to report the findings of these meetings to the Program Board;
- to provide an annual report to the Program Board, defining the achievements of the current year with respect to the Program objectives and recommending action necessary to further these objectives in the subsequent year; and,
- to make at least one site visit per annum to each approved Program component and to report the findings of these visits to the Program Board.

3.4 TECHNICAL REVIEW PANEL

In order to advise the Project Manager and to provide a forum for active participation of the many key parties involved, it is recommended that a Technical Review Panel be established. It would routinely report through the Project Manager, who would act as its chairman. However, the Program Board would have direct access to the Technical Review Panel should it feel this necessary or advisable at any time. It is recommended that the senior Canmet Project Officer and the mining industry representative on the Program Board also be members of the Technical Review Panel.

The functions of the Technical Review Panel would include:

- to assist the Board and/or the Project Manager on technical/scientific issues as required;
- to review reports and other aspects of the Program components relative to their technical, scientific or practical sufficiency as required;
- to provide a direct forum for the exchange of information between active participants in the Program on a regular basis; and,
- to propose specific recommendations to the Board as appropriate.

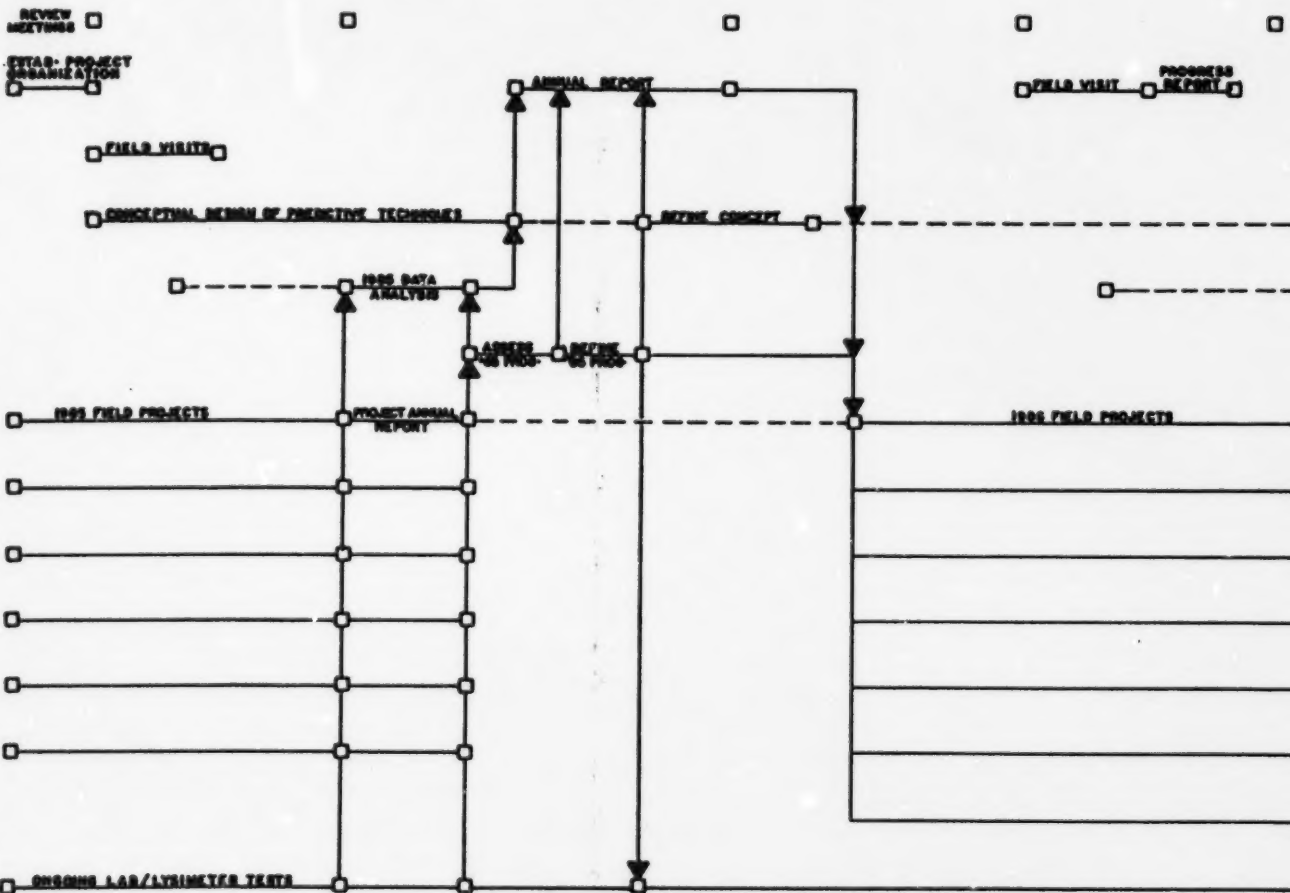
It is recommended that the membership of the Technical Review Panel be selected so as to represent, not only the various corporate, agency and regional interests indicated in Plate 3-1, but also that the individuals concerned be personally knowledgeable in one or more relevant technical or scientific aspects of acid-generating tailings so that the panel is well-qualified to truly advise on the content of the Program. It is suggested that persons knowledgeable in at least the following areas be involved and that consideration be given to increasing the membership of the Technical Review Panel slightly if this is necessary to achieve basic representation of the following areas:

- engineering design of tailings systems;
- biochemistry of acid-generating tailings;
- hydrogeology;
- plant ecology/agronomy;
- aquatic ecology; and,
- base metal processing/mine operations.

3.5 PROJECT SCHEDULE

The duration of the Reactive Acid Tailings Program is five years, and it is assumed that it will be feasible to commence activities on or before July 1, 1985, in order to take advantage of the 1985 field season. The proposed network diagram and schedule, as indicated in Plate 3-2, are based on these assumptions. This diagram does not attempt to show all the proposed program inputs listed in

1985						1986					
JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUN.



ENCO LIMITED

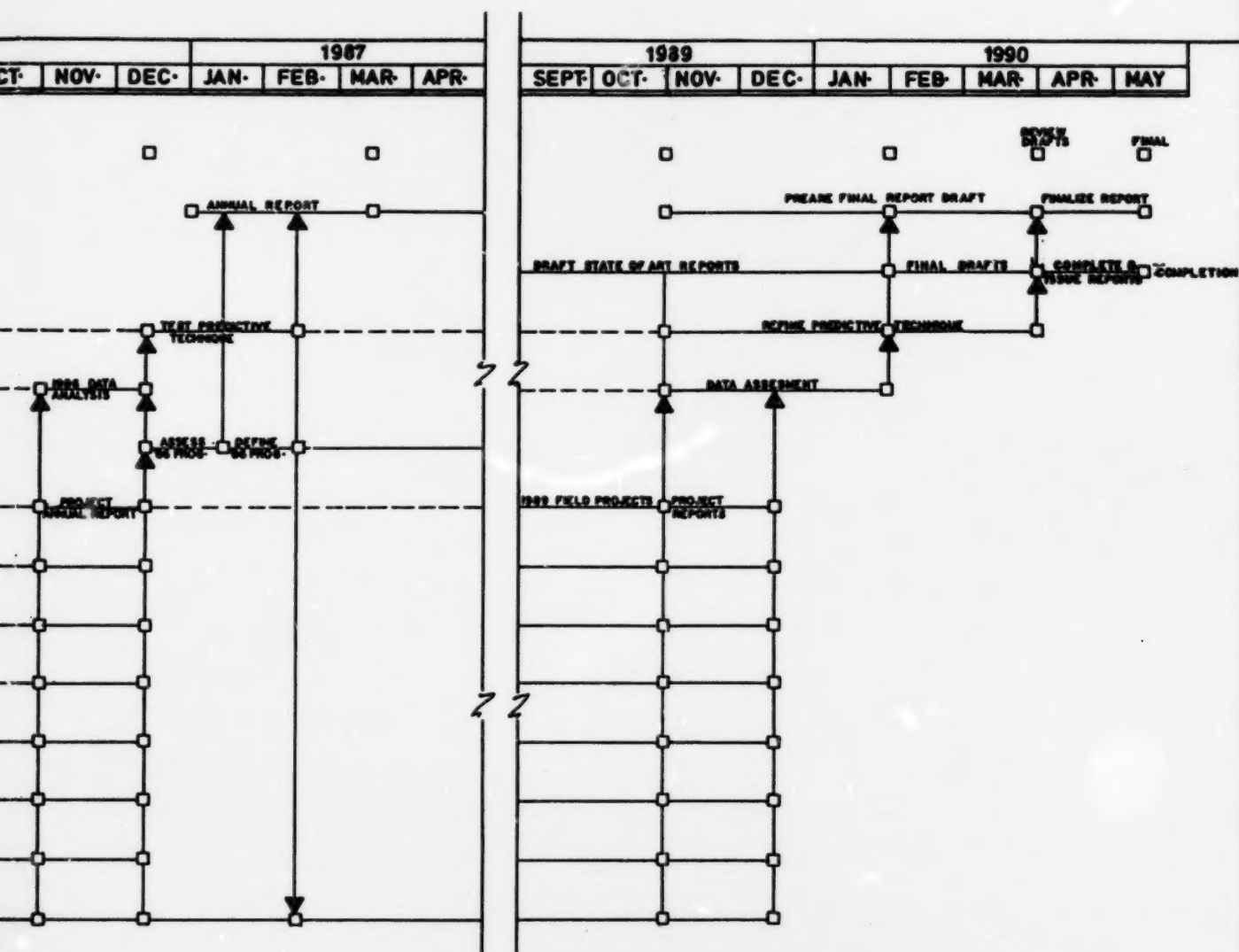


PLATE 3-2
REACTIVE ACID TAILINGS PROGRAM
ACTIVITY NETWORK DIAGRAM/SCHEDULE

Table 2-1, but is intended more to show the manner in which the Program will reflect the impact of the field season each year (i.e. May - October), with the analysis of project data and the preparation of individual project reports being completed before year end. Integration of the project results, definition of the following year's program, and the preparation and presentation of an overall Program annual report can then be achieved over the winter months.

Plate 3-2 indicates that the conceptual design of the predictive techniques would be undertaken as an initial program activity as discussed in Section 221, with testing and refinement as a function of the annual review of data. The diagram also indicates the key project management activities, including: establishment of the program organization (including the Technical Review Panel) in 1985; field visits to all projects at least once a year with a brief report to the Program Board on the status of each project; two meetings of the Technical Review Panel in 1985 with assumed quarterly meetings in subsequent years; preparation of the Program annual report; and coordination of the various activities required to consolidate the results of the Program during the final year.

3.6 PROJECT CONTROLS

As outlined in Section 3.1, the Reactive Acid Tailings Program will, by its nature, consist of a wide range of components being implemented by different corporations and agencies across the country. Strong management and well established project control procedures will therefore be required to achieve the objectives of the Program.

The following series of program reporting, assessment and refinement procedures are recommended as the basis of controlling the Program:

- Concise definition of objectives and budget for each sub-project.
- Monthly reporting by sub-project managers to the Program Manager. (A suggested reporting form is included as Plate 3-3.)

PROPOSED MONTHLY REPORTING FORM

REACTIVE ACID TAILINGS PROGRAM

MONTHLY REPORTING FORM

TITLE OF COMPONENT: _____ REPORTING PERIOD
 INDIVIDUAL RESPONSIBLE: _____ MONTH ____ YEAR ____
 OBJECTIVE OF THIS COMPONENT: _____

1. <u>BUDGET</u>	<u>CANMET</u>	<u>PROPONENT</u>	<u>TOTAL</u>
TOTAL PROJECT BUDGET			
APPROVED CURRENT YEAR			
FORECAST THIS MONTH			
ACTUAL THIS MONTH			
ACTUAL THIS YEAR			
FORECAST NEXT MONTH			
FORECAST TO COMPLETE YEAR			

2. SCHEDULE

MILESTONES COMPLETED: _____

KEY EVENTS NEXT MONTH: _____

DIFFERENCES FROM AGREED SCHEDULE: _____

3. DESCRIPTION OF ACTIONS THIS PERIOD:

4. PLANNED FOR NEXT MONTH:

5. WILL OBJECTIVES BE MET? _____

6. COMMENTS OR SUGGESTIONS (USE REVERSE IF NECESSARY):

SIGNED: _____

DATED: _____

- Quarterly progress reports by Program Manager to the Program Board. This would be a simple consolidation of the monthly project reports with an overall review and forecast for the next period. This report would form the basis of the quarterly meeting by the Technical Review Panel. A suggested typical agenda for these meetings is included as Plate 3-4.
- Annual Program report prepared by Program Manager and submitted to Program Board. Technical Review Panel would provide input to this report, which would review the achievement of objectives for the reporting period and define the program required during the subsequent year to meet future objectives.

REACTIVE ACID TAILINGS PROGRAM

TECHNICAL REVIEW PANEL

SUGGESTED AGENDA

1. MINUTES OF LAST MEETING
2. REVIEW OF ONGOING PROJECTS SINCE LAST MEETING
3. ACHIEVEMENTS/PROBLEMS TO DATE RELATIVE TO MEETING
OVERALL PROGRAM OBJECTIVES
4. REQUIRED INPUTS TO PROGRAM
5. MEANS OF ACHIEVING ITEM 4
6. OTHER MATTERS

PLATE 3-4
SUGGESTED TYPICAL AGENDA
FOR QUARTERLY TECHNICAL
ADVISORY PANEL MEETINGS

REFERENCES

REFERENCES

Boorman, R.S., and Watson, D.M., 1974. Chemical processes in abandoned sulphide tailings dumps and environmental implications for Northeastern New Brunswick. New Brunswick Research and Productivity Council.

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Monenco Limited, Cominco Limited, Inco Limited, and Noranda Inc. 1984. Sulphide tailings management study. Report to CANMET, Ottawa.

APPENDIX 1

**EXECUTIVE SUMMARY
SULPHIDE TAILINGS MANAGEMENT STUDY**

SULPHIDE TAILINGS MANAGEMENT STUDY

**A Joint Project of
Monenco Limited, Cominco Limited, Inco Limited
and Noranda Inc.**

29 June 1984

**Monenco Limited
500 Beaverbrook Court
Fredericton, New Brunswick
E3B 5X4**

EXECUTIVE SUMMARY

The objective of this study has been to define the measures that are required to resolve the concerns and difficulties associated with the long term management of acid generating sulphide tailings.

Disposal sites containing acid generating sulphide tailings are located throughout the base metal mining regions of Canada. Thus, New Brunswick, Quebec, Ontario, Manitoba, British Columbia, and the Yukon and Northwest Territories contain deposits of tailings which generate acidic, metals containing effluents. Most of the tailings deposits, which range in areal extent from a few hectares to over a 1000 hectares, are located in surface impoundments formed by the construction of dams. Fewer of the deposits are located in lakes and offshore (British Columbia) areas.

During the past 20 years or so, the mining industry has implemented reclamation measures to return minesites to an acceptable state following the completion of mining activities. However, acid generating sulphide tailings present a very difficult and somewhat unique situation as regards to the achievement of reclamation requirements. The generation of acid within the tailings deposits not only inhibits the growth of vegetation on the deposits but may also continue to produce acidic, metals containing effluents, long after cessation of mining activities. At this time, there are many uncertainties as to whether or not many of the base metal minesites can be reclaimed so as to allow for their abandonment with no further obligations to the owner or society in general.

It has been well established that the formation of acidic conditions is due primarily to the oxidation of the ferrous sulphide minerals contained by sulphide tailings. These minerals, principally pyrite (FeS_2) and pyrrhotite ($\text{Fe}_{1-0.8}\text{S}$), are often associated with base metal orebodies. The formation of acidic conditions requires exposure of the minerals to oxygen (air) and moisture, and is enhanced by the presence of certain microorganisms. The inhibition of the acid generation process has proven to be extremely difficult despite years of research and costly reclamation measures.

To date, reclamation measures have concentrated on the establishment of vegetation on tailings. It is apparent that successful site-specific revegetation techniques have been developed during the past few years after many years of research. However, revegetation can be prohibitively expensive and, most importantly, it has not been established that revegetation of acid generating tailings will adequately inhibit the generation of acidic, metals containing effluents. Possibly the most effective inhibition of acid formation has occurred for those cases in which sulphide tailings have been disposed of underwater. However, this is not a practicable method in all cases and, in any event, may not be permissible due to regulatory requirements.

Further research and development programs are required to develop technology for the long term management of acid generating tailings. There is a need to better understand the physical and chemical processes that occur within sulphide tailings disposed of under various field conditions. A better understanding of these processes will enable the development of more effective methods for the planning of sulphide mining operations and for the disposal of acid generating tailings.

It is estimated that a 3 to 5 year development program would cost in the order of \$2.5 million, not including the cost of services that would be provided by the mining companies. This development program would include the following activities:

1. Technology transfer to ensure that information concerning well established technologies is available to the mining industry (revegetation, current tailings disposal, and effluent control practices)
2. Development of prediction techniques related to the physical and chemical behaviour of tailings
3. Development of more effective methods for the disposal of tailings
4. Development of methods to inhibit and control the generation of acidity, and
5. Assessment of the specific benefits and effects of revegetation as an inhibitor of acid generation.

RECOMMENDED RESEARCH AND DEVELOPMENT PROGRAM

It is recommended that the following research and development programs be initiated in order to further develop technology for the long term management of acid generating tailings.

Technology Transfer

A series of reports should be prepared, describing current knowledge and providing guidance to mining companies and others. Topics would include relatively well-established technologies. There should be a provision for updating these reports periodically. It is recommended that manuals be developed initially for:

- the revegetation of acid generating tailings
- the design and operation of tailings disposal systems, and
- the control of tailings disposal area effluents.

Prediction Techniques

There is a need for better methods to predict the chemical and physical behavior of tailings (acid generation, consolidation . . .), based on sample parameters and/or experimental evaluations. Longer-term, it would be desirable to improve water movement models and develop chemical/physical transformation models (with the ultimate goal of integration of the models). It is recommended that programs be carried out to:

- Evaluate experimental techniques and recommend further research to develop methods to predict the degree of acid formation that can be expected due to sulphide mining and tailings disposal operations.
- Assess the practicability of using the physical/chemical properties of ore and tailings to predict changes with time (acid generation, leaching, conglomeration, dewatering . . .).

Tailings Disposal Systems

Better techniques are required for dewatering tailings, both to permit access for placing coverage and to minimize the period of consolidation (continuous weeping of contaminated water). Long-term structural stability as well as surface and subsurface hydrological factors (seasonal variations, dispersion patterns, flushing, maximum storms . . .) need to be better understood. The merits of tailings component segregation (e.g. -whether the formation of hardpan is beneficial or detrimental). It is recommended that programs be carried out to:

- Estimate the costs for current and prospective tailings disposal methods
- Monitor the physical and chemical properties of field scale tailings deposits (i.e. bacterial populations, oxygen levels, seepage, water quality, water content, particulate characteristics, conglomeration tendencies, etc.) for different tailings systems such as:
 - low acid generating, unvegetated
 - low acid generating, revegetated
 - high acid generating, unvegetated
 - high acid generating, revegetated
- Evaluate the merit of alternative cover techniques during operation and post-operation
- Evaluate the merits of tailings disposal system designs and operating techniques (pyrrhotite segregation, deposition methods . . .) with regard to such factors as tailings dewatering, tailings chemical and dam physical stability, ease of rehabilitation, water control.

Effluent Control

The monitoring, interception and treatment of waters from tailings disposal areas requires continuing attention, as regards to reliability and costs. Improved techniques for reducing the quantity and/or contamination of water (including control of chemical and bacterial oxidation) need to be developed and demonstrated. In-place passive techniques (injection of bactericide or neutralization agent) for both the short and long term treatment of sulphide tailings requires consideration. It is recommended that programs be carried out to:

- develop and demonstrate (laboratory and field scale) methods to decrease the generation of acid (SLS and other bactericides, oxygen and water cut-off techniques, in site neutralization, simpler and more economic methods for the neutralization and clarification of effluents).

Revegetation

The specific benefits and effects of revegetation need to be quantified. In addition, continued research is required as regards to "soil" preparation, species selection, and long term self perpetuation of vegetation. It is recommended that programs be developed to:

- demonstrate the establishment of long-term, maintenance free vegetation
- improve techniques for "soil" characterization, development of resistant plant species (i.e. cold, drought, acid), and techniques that minimize the requirements for borrow materials (clay, soil), and fertilizer.

APPENDIX 2

NOTES ON PROVINCIAL MEETINGS

Ste-Foy, Quebec
April 30, 1985

REACTIVE ACID TAILINGS PROGRAM

Place: Quebec Ministry of Environment
3900 Marly Street
Ste-Foy, Quebec

April 30, 1985
9:00 a.m.

Present: Conrad Anctil, Ministry of Environment
John Barter, Monenco Limited
Alan Bell, Monenco Limited
Edwin Joe, Energy Mines & Resources Canada
Raynald Ouellet, Ministry of Environment
Denis Paquet, Compagnie Miniere
G.H. Pelletier, Noranda Inc.
Richard S. Siwik, Noranda Research
Pierre Vezina, Ministry of Environment

Observers: Jules St-Larent, Hydrosemenace de l'Estrie Ltee.
Serge Langlois, Hydrosemenace de l'Estrie Ltee.

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7. Proposals for Jointly Funded Projects

Meeting Notes

A.V. Bell reviewed items 1 through 4.

Questions and Comments

- There were a number of questions concerning the scope of the project, specifically whether iron-ore tailings (non-sulphide) would be included and whether the program would address reclamation methods for new tailings systems or merely clean-up methods for existing deposits.
- The chairman was asked to review key points arising from other provincial meetings and this promoted considerable discussion on a wide range of technical and regulatory issues.
- The point was made that the Quebec Ministry of Environment (MENVIQ) have very limited staff resources in dealing with acid mine tailings and are essentially limited to those representatives present at the meeting.

Provincial Regulatory and Management Objectives

- MENVIQ classifies its approach to mine tailings into two groups: one concerned with future developments, under Raynald Ouellet, and the other looking at the restoration of abandoned sites under Pierre Vezina (GERLEDD).
- Directive 019 gives guidelines on mine waste management. Guy Pelletier noted that a government industry committee was formed last November but has yet to meet.
- Quebec Ministry of Energy, Mines and Resources have proposed a 25% government grant to help restore existing waste sites, which would include acid generating tailings. However, the program has yet to be approved.
- GERLEDD (Groupe d'Etudes et de Restoration des Lieux d'Elimination des Dechats Dangereux) does not envisage any project financing and will be expecting industry to pay for reclamation work once an owner of the site is identified.
- MENVIQ have a similar policy to Ontario in that they will look at sites on a case-by-case basis taking into account the impact and assimilative capacity of the receiving systems.

Proposals for Jointly Funded Projects

- Richard Siwik of Noranda Research, briefly outlined the work proposed at the Waite Amulet tailings site. A summary of this program is attached.
- MENVIQ have three problem sites which they may wish to include in the RATS program: Milles Poirier (owned by Rio Algom), Aldermac (owned by New Emsco) and McWaters.

The meeting was adjourned at 11:45.

Toronto, Ontario
April 18, 1985

REACTIVE ACID TAILINGS PROGRAM

Place: Ontario Mining Association
Richmond Street West
Toronto, Ontario

April 18, 1985
9:00 a.m.

Present: Alan Bell, Monenco Limited
Colin Chapman, Kidd Creek Mines Limited
Peter Crabtree, Environment Ontario
Charlie Ferguson, Inco Limited
Edwin Joe, Energy Mines & Resources Canada
Margarete Kalin, Boojum Research Ltd
Bill Logan, Ministry of Natural Resources
Unco Nakano, Kidd Creek Mines Limited
Mike Paradis, Ministry of Natural Resources
Cal Warden, Ministry of Natural Resources
John Weglo, Falconbridge Limited

Observers: Murray Dixon, University of Toronto
Caroline Schultz, University of Toronto

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Meeting Notes

A.V. Bell reviewed items 1 through 4.

Questions and Comments

During Questions and Comments, the following points were raised:

- Charlie Ferguson is currently preparing a paper on predictive techniques as they apply to mine development for presentation at the Banff School of Environmental Studies next fall.
- It was suggested that a newsletter for the RATS Program would be a good idea to update interested parties, but it was agreed that distribution of Steering Committee minutes might suffice and involve less overhead time.
- Enhanced leaching techniques may be applicable to tailings deposits, particularly as leaching used for beneficiation often encounters a surface coating layer, thus blocking further leaching of metals.
- Pyrrhotite deposits in the Sudbury area (Inco and Falconbridge) remain unoxidized if kept wet, but instantly combust if dried and exposed to the atmosphere.
- Capping sulphide tailings with a layer of pyrrhotite with a view to deliberately encouraging development of hardpan may be an approach worth considering.

Provincial Regulatory and Management Objectives

- Three provincial agencies are involved in reclamation procedures: Labour, Environment and Natural Resources. The delineation of responsibility is not well defined but, in general, Natural Resources are concerned with on-property issues, whereas Environment focus more on the off-property impacts.
- MOE will assess each situation on a case-by-case basis, considering the effects and assimilative capacity of the surrounding environment. The Ministry has established objectives in the form of guidelines which are non-legal and will write these into a "control order" for specific situations, which then has legal status.

Proposals for Jointly Funded Projects

- Charlie Ferguson asked Margarete Kalin of Boojum Research Limited to present the series of studies proposed for the Levack tailings area. A summary of the program is attached.
- John Weglo of Falconbridge outlined three projects which his Company might submit for inclusion in the RATS Program. These include:
 - 1) an evaluation of an acid bog close to the smelter, which is showing excellent signs of recovery and a very diversified range of plant life;
 - 2) evaluation of the use of municipal garbage as a covering to an abandoned tailings site; and,
 - 3) investigation of a pyrrhotite tailings area which has been covered with gravel and which appears to provide a barrier for upward migration of acid.

Mr. Weglo will provide brief write-ups on these projects to A.V. Bell for consideration as inputs to the RATS Program.

- Mike Paradis, Ontario Ministry of Natural Resources in Timmins, mentioned that his Department has been undertaking investigations on an abandoned high-sulphur tailings and will submit a write-up on this work for possible inclusion in the Program.
- Kidd Creek Mines have a large tailings area (3000 acres) but, since the total area is active and being operated in accordance with the Roblinski method of placement, it is not feasible to undertake reclamation-related research at this time.
- It was suggested that research into thio-sulphate stabilization be considered but Eddy Joe of Canmet pointed out that funding in the order of \$700,000 had already been applied to this problem and that a wealth of information existed. A pilot treatment operation for thio-salts is still being operated by Noranda Research at the Brunswick Mining property in New Brunswick.

The meeting was adjourned at 12:00.

Fredericton, New Brunswick

April 16, 1985

REACTIVE ACID TAILINGS PROGRAM

Place: Monenco Limited
500 Beaverbrook Court
Fredericton, New Brunswick

April 16, 1985

Present: Alan V. Bell, Monenco
Roy Burke, Heath Steele Mines
Eddy Joe, Canmet
Jim Johnstone, Heath Steele Mines
Vaclaf Kresta, NB Environment
Katharine MacLaggan, NB Environment
John Martin, Brunswick Mining
Keith Phinney, Monenco
Jim Schnarr, Brunswick Mining
Ken Wheeland, Noranda Research

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Meeting Notes

A.V. Bell reviewed items 1 through 4.

Questions and Comments

During questions and comments, the following points were raised:

- Development of predictive models for the geochemical behaviour of sulphide tailings within the tailings mass was felt, by some, to be very ambitious due to the variability in chemical and physical parameters. It was felt that modelling the external effects of a tailings storage area might be more realistic.
- It was felt that emphasis should be placed on establishing practical solutions, and the program should not be allowed to become too theoretical or "hung up" on modelling aspects.
- Brunswick have established vegetation on their metal treatment sludge pond using hydroseeding. Heath Steele Mines are now disposing of their hydroxide treatment sludges into the tailings pond (there are no tailings being produced at this time). This affords an opportunity to investigate the effects of covering tailings with hydroxide metal sludges and revegetating this cover.
- In discussing the relative merits of flooding tailings areas, V. Kresta pointed out several advantages to a flooded system, including the elimination of dusting and the effects of surface water erosion. K. MacLaggan, on the other hand, expressed a personal preference for vegetation as the primary vehicle for reclamation.

Provincial Regulatory and Management Objectives

- The question of whether tailings deposits revert to the Crown is not established in New Brunswick, but it was felt to be unlikely that the Crown would relieve the mine of responsibility for reclamation or ongoing treatment.
- The New Brunswick Mining Act requires submission of a reclamation plan~~y~~ to be approved by the Ministers of Natural Resources, Environment and Agriculture.

- It was suggested that the RATS Program should include recommendations on the regulatory aspects of reclaiming acid-generating tailings.
- The goal in New Brunswick would be for non-toxic effluents after all reclamation measures are complete. Abandonment plan should also provide for a single point of discharge.

Proposals for Jointly Funded Projects

- Brunswick Mining will submit a program to examine the suppression of dusting on tailings ponds. There was some discussion as to whether this was more an operating problem, but the point was made that the majority of mines would have large areas which would require at least interim dusting control during the establishment of longer-term reclamation measures. It was therefore agreed that this proposal would be considered for inclusion in the program.
- Brunswick might also want to consider separating the 15% non-pyrite in its tailings as a final float for use in covering tailings. They may be able to benefit from a tin byproduct, which would cover the incremental costs of floatation.
- Heath Steele Mines will give consideration to the possibility of investigating the effects of hydroxide sludges as a cover to sulphide tailings, but are not able to provide funding due to their current non-operational status.
- It was generally agreed that, funding problems aside, the Heath Steele situation provides an ideal situation for testing a number of reclamation measures, and this should be considered in developing the RATS Program scope.
- Ken Wheeland outlined the Waite Amulet proposed program. These tailings have high acid generation (30% sulphur). Sixty percent of the area is revegetated, forty percent not. They expect to get answers as to whether vegetation is self-sustaining or not over the long term, and will examine the geochemistry of the deposit as well as comparing the validity of lysimeters relative to the actual behaviour of the tailings area.

Winnipeg, Manitoba
April 4, 1985

REACTIVE ACID TAILINGS PROGRAM

Place: Manitoba Department of Energy & Mines
555-330 Graham Avenue
Winnipeg, Manitoba

April 4, 1985
9:00 a.m.

Present: Hedley Duffield, Manitoba Energy & Mines
Alan. V. Bell, Monenco Limited
Wayne Fraser, Hudson Bay Mining & Smelting Co. Ltd.
Winton Newman, Mining Association of Manitoba
Edwin Joe, Energy Mines & Resources Canada
Graham Holmes, Sherritt Gordon Mines Limited
Dave Matheson, Acres International
Dennis Brown, Env. & Workplace Safety & Health
Clem Moche, Env. & Workplace Safety & Health
Brian Bailey, Manitoba Energy & Mines
John Ashton, Inco Limited
Bill Bardswich, Manitoba Energy & Mines

Agenda

1. Introduction
2. RATS Objectives and Approach
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4. Review of Recommended Research Requirements
5. Questions/Comments
6. Provincial/Industry Programs
7. Review of Provincial Regulatory and Management Objectives
8. Proposals for Jointly Funded Projects

Meeting Notes

A.V. Bell reviewed items 1 through 4.

During questions and comments, the following points were raised:

- The need for provincial representation on the RATS Steering Committee was emphasized, as was the need to extract as much relevant information from the potash, uranium and gold producers programs.

Provincial/Industry Programs

- Mr. Bill Bardswich outlined the Manitoba/Canada Mineral Development Program, which has a current funding level of \$27 million and includes \$1.1 million for tailings research. The overall objective of the program is to "strengthen and diversify the mineral base in Manitoba". They have recently awarded a project to Acres International to study the natural aging process of abandoned tailing sites in Manitoba. This will include chemical characterization of the tailings profiles, groundwater investigations, etc. The results should be available at year end, and there was general enthusiasm for a high level of cooperation between this program and RATS. It was agreed that duplication should be avoided.
- Manitoba Energy & Mines would very much like to see some research on underwater/lake disposal of tailings as an integral part of RATS.

Proposal for Jointly Funded Projects

- John Ashton advised that the Inco tailings were too young, but that he would be very interested in the development of predictive techniques and also in determining whether hardpan is a naturally limiting factor in the oxidation of tailings.
- Graham Holmes of Sherritt advised that the Provincial program will cover their requirements, and the mine has no current plans for major expenditures on research. They may, however, have inputs for the program relative to the Fox Mine closure, including a monitoring scheme for abandonment, which would start October '85.
- There is a need for the "Crown" to look at the Sheridan tailings area (an abandoned property owned by the Crown) which spills into a watercourse and is adversely affecting water quality.

- Wayne Fraser of Hudson's Bay stated that his Company was currently short of funds, but mentioned that at Anderson Lake they were involved in underwater tailings disposal, which might be of interest to the program, if the means to undertake studies could be determined. He also mentioned the possibility of a new zinc smelter in the Province, if funding assistance can be found.
- Mr. Bill Bardswich thanked all present for their participation and re-emphasized the desire of his Department in achieving a close working relationship between the Federal/Provincial Mineral Development Program and the RATS Program.

The meeting adjourned at 11:30.

Victoria, British Columbia

April 2, 1985

REACTIVE ACID TAILINGS PROGRAM

Place: B.C. Ministry of Environment
810 Blanchard Street
Victoria, British Columbia

April 2, 1985

Present: Alan V. Bell, Monenco Limited
Fred P. Hodgson, B.C. Ministry of Environment
J.C. Errington, Energy Mines & Petroleum Resources
Malcolm J.R. Clark, B.C. Ministry of Environment
Edwin G. Joe, Energy Mines & Resources Canada
John Kwong, Energy Mines & Petroleum Resources
Jim Wright, Placer Development Limited
Ben Kangasniemi, B.C. Ministry of Environment
Norm Ringstad, B.C. Ministry of Environment
Murray Galbraith, Energy Mines & Petroleum Resources
Bob Gardiner, Cominco Limited
Bill Wakabayashi, Cominco Limited
Jim Robertson, B.C. Mining Association
Lance Regan, B.C. Ministry of Environment
J.D. Clark, B.C. Ministry of Environment

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8. Provincial/Industry Programs

Meeting Notes

A.V. Bell reviewed items 1 through 4.

During questions and comments, the following points were raised:

- Disposal of acid-generating waste rock is a serious problem in B.C., and several attendees questioned whether waste rock should be included in the program. However, the scope of the program is limited to tailings. While the chemistry may be similar, the physical aspects of waste rock disposal, as compared to tailings, are quite different.
- Consideration should be given to the use of sulphide tailings as mine backfill, although the slimes portion would still be left for disposal and these are normally the higher sulphide fraction.
- Development of predictive techniques is particularly important, and it was felt by many that this should be achievable as the chemistry of sulphide oxidation is well known.
- The program should find ways to incorporate experience from the U.S., Europe, Malasia, etc.
- In British Columbia, one is normally looking at covering tailings prior to establishing vegetation, rather than direct establishment on sulphide tails.
- Wetland vegetation has established naturally at Sullivan, but is not regarded by them as a practical method for large areas.
- It was recommended that the program include an evaluation of the cost effectiveness and longevity of the use of non-permeable membranes, geotextiles, etc., as covers to inhibit sulphide oxidation.
- The importance of defining the time frame and objectives for sulphide tailings management were felt to be important.
- A number of representatives present felt that natural stabilization processes should be investigated and better understood and thought that acid generation in general terms decreases with time. Solutions should look to enhance these natural processes.
- British Columbia has sulphide tailings disposal into deep-water lakes and, the general impression is that there are few serious problems associated with this approach. Jack Benson Lake has been monitored and a report should be available from B.C. Environment.

- Configuration of the final tailings disposal area is important, with a final convex surface greatly assisting long-term stabilization.
- The Sullivan Mine currently have a consultant drilling their tailings deposits to determine the physical characteristics of tailings at depth.
- B.C. Research is currently undertaking some work on rates of acid generation on Cominco tailings.
- It will be important to establish criteria by which to judge the success of long-term management measures.

B.C. Government Objectives

- Each location is recognized as being unique.
- There is currently considerable discussion as to whether tailings revert back to the Crown in the case of abandoned mines. In Saskatchewan, the operator owns tailings in perpetuity while, in Ontario, tailings return to the Crown once an abandonment plant is accepted.
- New mines in B.C. must submit a reclamation plan for approval and post a bond, but older mines are not subject to the bonding procedure. Consideration is being given to the government becoming directly involved in reclamation measures on abandoned properties.

Research Inputs

- Bob Gardiner of Cominco made a brief presentation of the program they are undertaking at the Sullivan Mine. This involves an area of 1.6 acres, which will be covered with float rock and then gypsum and revegetated. The site has already been established, representing the major cost of the program. Monitoring data will be made available to the government and the RATS Program.
- Jim Wright of Placer Developments Limited pointed out that their acid-generating problems related more to waste rock than tailings and he did not foresee any potential for jointly funded program relating to tailings at Placer.
- Jim Robertson of Tech Corporation, who was representing the B.C. Mining Association, advised that Tech do not have an acid-generating tailings problem, but he would relay the details of this meeting to the Mining Association, which would be meeting in a couple of weeks.

- It was suggested that the sub-area deposition approach being used by Westmin be further investigated.

Provincial/Industry Programs

- There is currently an investigation of backfilling acid-generating waste rock under the ultimate water table of the abandoned mines. Mixing of tailings with waste rock has been considered as a way to reduce the permeability of acid-generating waste piles.
- The B.C. Government will not be able to directly contribute to funding of programs in relation to RATS during 1985, but will be prepared to consider any requests for assistance during the '86-'87 fiscal years.

In closing, a number of representatives emphasized the importance of strong management of the RATS Program, including regular regional reviews.

Meeting was adjourned at 11:45 a.m.